SPEED ESTIMATION TECHNIQUES FOR INDUCTION MOTOR USING DIGITAL SIGNAL PROCESSING

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MASTER OF ELECTRICAL ENGINEERING

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion this thesis is satisfactory in terms of scope and quality for the award of the degree of Master of Engineering (Electrical).

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I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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LIST OF SYMBOL AND ABREVIATION

PWM	**Pulse Width Modulation**
AC	**Alternating current**
HP	**HP Horse Power**
ANN	**Artificial Neural Network**
S	**Slip**
R1	**Stator resistance in ohms**
R2	**Rotor resistance referred to stator in ohms**
R0	**Equivalent resistance corresponding to the iron losses in ohms**
L1	**Leakage inductance of Stator in henry**
L2	**Leakage inductance of Rotor referred to stator in henry**
L0	**Magnetizing inductance of the stator in henry**
X1	**Leakage reactance of Stator in ohms**
X2	**Leakage reactance of Rotor referred to stator in ohms**
X0	**Magnetizing reactance of the stator in ohms**
Vi	**Input voltage in volts**
V0	**Output voltage in volts**
V1	**Voltage across the variable rotor resistance in volts**
Vf	**Output voltage due to forward field in volts**
Vb	**Output voltage due to backward field in volts**
V0	**Output voltage**
I	**Current flowing through the stator in Amps**
I1	**Iron-loss and magnetizing component of the noload current in Amps due to forward field**
I2	**Rotor current referred to the stator in Amps due to forward fiel**
I3	**Iron-loss and magnetizing component of the noload current in Amps due to backward field**

I4	**Rotor current referred to the stator in Amps due to backward field**
Pgf	**Airgap power developed by the motor due to forward field**
Pgb	**Airgap power developed by the motor due to backward field**
T	**Torque developed by the motor in Nm**
TL	**Load Torque in Nm**
Ns	**Synchronous speed in rps**
J	**Moment of inertia in Kgm2**
B	**Viscous friction in Nms**
P	**Number of Poles**
ω	**Angular speed in rad/sec**
θ	**Angular displacement in radians**
Y	**Output vector of the hidden layer**
O	**Output vector of the output layer**
Vji	**weight matrix**
Wkj	**weight matrix**
B1	**Bias vector**
B2	**Bias vector**
Tr	**Input**
Lr	**Output**
Rr	**Secondary time constant**
Lm	**Secondary inductance per phase**
Rs	**Secondary resistance per phase**
Ls	**Magnetizing inductance per phase**
v	**Primary winding resistance per phase**

ABSTRACT

Speed estimation is one of the methods of speed sensor-less control for three phase induction motors. With the advancement of the power electronics switching devices and digital technologies, the developments of speed estimation methods have been intensively implemented from many researchers. Thus, this field of research has become more interested to investigate. Speed sensor-less control techniques can make the hardware simple and improve the reliability of the motor without the introducing the feedback sensor and it becomes more important in the modern AC servo drive. It is one of the attracting research directions in the high-precision servo control field because of its robust characteristics, simple realization and excellent dynamic response. Several common rotor speed estimation was introduced in the thesis. The model must accurately represent both the electrical and electromagnetic interactions within the machine and associated mechanical systems. In this Thesis, the neural networks controller for speed estimation has been developed approach to induction motor that has been implemented in digital signal processing controller (DSP) and gave the control signal to IGBT for run three phase inductions motor. Analysis of speed estimation nonlinear characteristics is carried out and makes a comparison with traditional linear method speed sensor less method. First, the simulation of the proposed control system is performed by using the MATLAB software and then the real time implementation is performed by using the MATLAB and the hardware. According to the mathematical model of the induction motor, the simulation of model and hardware implementation of speed sensor-less induction motor had been successfully implemented. The design and implementation of the speed estimation system for three-phase induction motor and the experimental research is presented in this Thesis. Finally, this Thesis shows the implementation of the speed estimation using DSP controller and the design of hardware and software for speed sensorless of induction motor. The experiment is completed at different speed and experiment results show that artificial neural network controller obtained a good response when compared to conventional methods.

ABSTRAK

Anggaran kelajuan adalah salah satu kaedah kawalan kelajuan sensor-kurang selama tiga fasa motor aruhan. Dengan kemajuan elektronik kuasa menukar peranti dan teknologi digital, perkembangan kaedah anggaran kelajuan telah dilaksanakan dengan intensif daripada ramai penyelidik. Oleh itu, bidang penyelidikan ini telah menjadi lebih berminat untuk menyiasat. Teknik sensor-kurang kawalan kelajuan boleh membuat mudah perkakasan dan meningkatkan kebolehpercayaan motor tanpa sensor maklum balas memperkenalkan dan ia menjadi lebih penting dalam pemacu servo moden yang AC. Ia merupakan salah satu arah penyelidikan yang menarik dalam bidang kawalan servo kepersisan tinggi kerana ciri-ciri yang teguh, kesedaran mudah dan gerak balas dinamik yang sangat baik. Beberapa kelajuan biasa anggaran pemutar telah diperkenalkan dalam tesis. Model harus secara tepat mewakili kedua-dua interaksi elektrik dan elektromagnet dalam mesin dan sistem mekanikal yang berkaitan. Tesis ini, pengawal rangkaian neural untuk anggaran kelajuan telah dibangunkan pendekatan untuk motor aruhan yang telah dilaksanakan dalam pemprosesan isyarat digit pengawal (DSP) dan memberi isyarat kawalan ke IGBT untuk jangka masa tiga fasa motor induksi. Analisis ciri-ciri tak linear anggaran kelajuan dijalankan dan membuat perbandingan dengan kelajuan tradisional kaedah linear kaedah sensor yang kurang. Pertama, simulasi sistem kawalan yang dicadangkan dijalankan dengan menggunakan perisian MATLAB dan pelaksanaan masa nyata dilakukan dengan menggunakan MATLAB dan perkakasan. Menurut model motor aruhan matematik, simulasi model dan pelaksanaan perkakasan kelajuan sensor-kurang motor aruhan telah berjaya dilaksanakan. Reka bentuk dan pelaksanaan sistem anggaran kelajuan motor aruhan tiga fasa dan penyelidikan eksperimen dibentangkan di dalam tesis ini. Akhirnya, Tesis ini menunjukkan pelaksanaan anggaran kelajuan menggunakan DSP pengawal dan reka bentuk perkakasan dan perisian untuk sensorless kelajuan motor aruhan. Eksperimen itu selesai pada kelajuan yang berbeza dan hasil eksperimen menunjukkan bahawa pengawal rangkaian neural tiruan mendapat sambutan yang baik berbanding dengan kaedah konvensional.

REFERENCES

Bose B.K, 2007. Neural Network Applications in Power Electronics and Motor Drives, An Introduction and Perspective. Trans. on Industrial Electronic. **54**.

Bartolini G, Damiano A, Gatto G, Marongiu I, Pisano A, and Usai E, 2003. Robust speed and torque estimation in electrical drives by second order sliding modes. *IEEE Trans. Control Syst. Technol.* **11**: 84-90.

Bolognani S, Tubiana L, and Zigliotto M, 2003. Extended kalman filter tuning in sensorless pmsm drives,. *IEEE Transactions on Industry Applications*. **39**: 1741-1747.

Bonkas T.K, Habetler T.K, 2004. High-performance induction motor speed control using exact feedback linearization with state and state derivatice feedback. *IEEE Trans. on Power Electronics*. **19**: 1022-1028.

Briz F, Diez A, and Degner M.W 2002. Dynamic operation of carrier signal injection based sensorless directed field oriented AC drives. *IEEE trans Electron*. **65**: 13601368.

Buja, G. S, Kazmierkowski, M.P., 2004. Direct torque control of PWM inverter-fed AC motors *IEEE trans Electron*. **51**: 744-757.

Escobar G, Stankovic A.M, Galvan E, Carrasco J.M, 2003. A family of switching control strategies for the reduction of torque ripple in DTC,. *IEEE Trans. on Control Systems Technology* **11**(6): 933-940.

Fitzgerald. A, Umans S.D, 2006. Quadratized Three-Phase Induction Motor Model for Steady-State and Dynamic Analysis. *Electric Machinery, 6th*. **72**: 79-89.

Holtz, J.2006. Sensorless Control of Induction Machines – With or Without Signal Injection. *IEE Elect. Power Applicat*. **53**: 7-30.

Ilas C, Ferraris L, Griva G and Prohmo F, 2005. Comparison of different schemes without shaft encoders for field oriented control drives. IECON 2005. Bologna Itali.

Kubota H and Matsuse K, 2005. Speed sensorless field oriented control of induction machines using flux observers. !ECON 2005. Bologna, Italy.

Kim Y.R, Sul S.K and Park M.H, 2007. Speed sensorless vector control of induction motor using extended Kalman filter. *IEEE trans industry Application*. **30**: 1225-1233.

Lascu C, Boldea I, Blaabjerg F, 2005. Very-low-speed variable-structure control of sensorless induction machine drives without signal injection. *IEEE Trans. Ind. Appl.* **41**(2): 591-599.

Lai Y.S and Chen J.H ,2001. A new approach direct torque control of induction motor drives for constant inverter switching frequency and torque ripple reduction. *IEEE Trans. Energy Conversion,*. **16**(3): 220-227.

Lee K.B, Blaabjerg F, 2005. Disturbance observer that uses the radial basis function networks for low speed control of electric machine. *Inst. Elect. Eng., Contr. Theory Appl.* **152**: 118-125.

Lee K.B, Choy I, and Yoo J.H, 2001. Improvement of lowspeed operation performances of DTC for 3-level inverter-fed induction motors,. *IEEE Trans. Ind. Electron*. **48**: 1006-1014.

Leksono Edi, 2000. Fuzzy Auto Reset Controller For Speed Sensorless Induction Motor Drive. IECON 00. Nagoya, Japan.

Lin F, Wan C.Y, 1999. Sliding mode and fuzzy control of toggle mechanism using PM synchronous servomotor drive. *IEE Elect. Power Applicat*. **144**: 393-402.

Mohamadian M.N, Ashrafzadeh F, 2003. A novel neural network controller and its efficient DSPimplementation for Vector-controlled induction motor drives. *IEEE TraNs. iND. Applicat*. **39**: 1622-1629.

Ouhrouche M. A, 2002. Estimation of Speed, Rotor Flux and Rotor Resistance in Cage Induction Motor using EKF algorithm,. *International Journal of Power and Energy Systems*. **22**: 1201-1211.

Panigrahi B.P, 2007. A simple hardware realization of switching table based direct torque control of induction motor. *Elsevier*. **77**: 181-190.

Panigrahi B.P, 2005. Digital Simulation and PC based implementation of switching table based Direct Torque Control of induction motor drive. IIT conference. kharagpur.

Pisano. A.D, Fridman.L, and Usai.E.2008. Cascade control of PM DC drives via second-order sliding-mode technique. *IEEE Transactions on Industrial Electronics,*. **55**: 3846-3854,.

Qiang Lu, Xiao-long Ji, and Meng Yong-qing, and Proceedings of the CSEE, vol.26, pp.164-168 2006. A novel sliding-mode observer for speed-sensorless induction motors. *Elsevier*. **26**(CSEE): 164-168.

Qinghui Wu, et al.2009. Research on neural network inverse model of induction motor drives. *IEEE JOURNAL*. **9**.

Song J.L, Song J.H, Choy I, Kim K, 2000 IEEE Industry Applications Society Conference, vol. 3, pp. 1828-1834, Sensorless vector control of induction motor using a novel reduced-order extended Luenberger observer. *IEEE Industry Applications Society Conference,*. **3**: 1828-1834.

Trzynadlowski A.N, 2005. The field orientation principle in control of induction motors. *MA Kluwer Academic*. **7**: 201-206.

Wan Jun,Wan Min, and Ma Yan-bing, Proceedings of the CSEE, 2005.2005. Speed sensorless drive of induction machine using fundamental frequency current injection. *Elsevier*. **25**(CSEE): 163-167.

Xu Z and Rahma M.F, 2007. Direct torque and flux regulation of an ipm synchronous motor drive using variable structure control approach. *IEEE Transactions on Power Electronics*. **22**: 1198-1214.

Xianzhong Dai, Guohai L, 2006. Neural network inverse synchronous control of two-motor variable frequency speedregulatingsystem. ICNSC 06. BEIJING, CHINA.

Xianzhong, W. X, 2007. The ANN inverse control of induction motor with robust flux observer based on ESO. *IEEE JOURNAL*. **7**: 196-205.

Zhao Dezong, and Hao Lan-ying, 2007. A robust sliding-mode control strategy of a speed sensorless induction machine
Elsevier. **26**: 122-127.

Zulkarnain Lubis, Ahmed. N. Abdalla, Mortaza bin Mohamed, Ruzlaini Ghoni, SollyAryza, 2010. A Novel Nonlinear Torque And Current Control of the Induction Motor Couple DC Motor MUCET 10. Pahang, Malaysia.